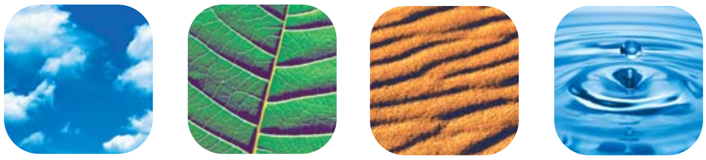

A COMMERCIAL APPLICATION OF VIROMINE™ TECHNOLOGY

CASE STUDY: ROSSARDEN

"In 2004 Mineral Resources Tasmania (MRT), of the Department of Infrastructure, Energy and Resources, undertook extensive trials at Rossarden mine site; with Virotec applying its ViroMine™ Technology to remediate the tailings and prepare the site for revegetation."

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BACKGROUND

Rossarden in north-eastern Tasmania, about 20 kilometres north of Avoca, is home to the former Aberfoyle Tin Ltd tin and tungsten mine, which began production in 1931. The mines at Rossarden and Storys Creek have been abandoned since the early 1980s, and accumulated zinc- and copper-contaminated tailings have been stored in several dumps, posing an environmental risk.

In 2004, Virotec Global Solutions secured a contract by tender offered by Mineral Resources Tasmania (MRT) of the Department of Infrastructure, Energy and Resources to conduct extensive trials applying its ViroMine™ Technology to remediate the tailings and prepare the site for revegetation. This case study provides a general background to the Rossarden mine site, documents Virotec's initial research and on-site trials and presents recommendations for future work using the ViroMine™ Technology.

Figure 1: A 1931 view of the Rossarden mine site with, from left to right, the blacksmith's building, the mill building and the main shaft.

HISTORY

Early exploration and development of the Rossarden mine were conducted in the years from 1928 to 1930. During that time mineralisation was found and initial infrastructure was installed. The mine began operation in 1931 after an eight kilometre water race was connected to a natural stream at the base of Ben Lomond to transfer water to a large dam built near the mine.

The mine site was developed further in the mid-1930s and the operating plant was electrified in 1937. Further work in 1939 completed the No. 2 shaft (the "Brandon Shaft") to a depth of 408 feet from the surface; and in 1940 the mine installed a new steel head frame, electric hoist, and a flotation unit to remove sulphide impurities and improve the quality of tin concentrates at the processing plant. Grinding and flotation units completed in 1941 made it possible to produce a high-grade concentrate.

The Rossarden mine operated steadily and was moderately productive from the 1940s to the 1960s, although production slowly declined and the mine gradually became run down. The mine was

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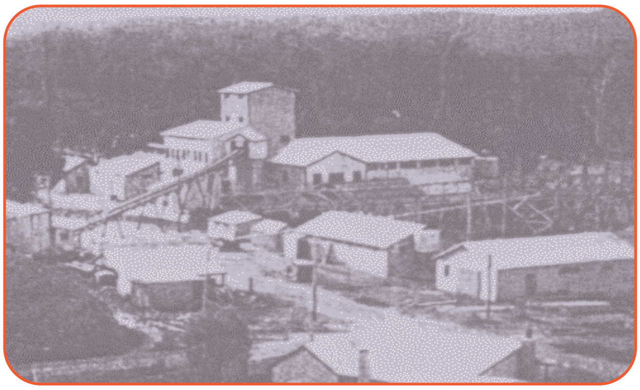

Figure 2: A view of Spiers Shaft and the main mill building from the Brandon Shaft looking north east c.1940.

revitalized in 1968 with an injection of funds after the Lutwyche lode was located with tested reserves of over 340,000 tons of ore. At this time the mine employed 252 people (150 worked underground) with good prospects for more employment.

In April 1981, Forestwood Holdings took over the lease from Aberfoyle Tin Ltd and invested in new equipment and facilities but just one year later the mine suddenly closed. In February 1982 the Rossarden tin mine dismissed three-quarters of its work force and closed the underground mine, which had operated for 50 years. The closure resulted from the failure of the Lutwyche ore deposit to reach the expected grade and the discovery of a major fault that limited the amount of ore that could be mined. The company retained 40 workers to rework the tailings, but this number soon dropped to five.

Closure of the mine left an environmentally impaired site and in 1992 the Department of Mines started to clean up the derelict site, beginning with the removal of old buildings. In 1997, Mineral Resources Tasmania noted that although the Storys Creek and Rossarden mines had been important tin and tungsten producers they also had major environmental impacts including discharges of tailings and contaminated water into Storys and Aberfoyle Creeks.

Figure 3: A night view of the Rossarden mine c.1965.

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Figure 4: A view of accumulated zinc-enriched tailings at Rossarden in 2001.

The discharge of acidic metal-laden water from the derelict workings continue from the workings and although the impact of the acidity is localised, fish with elevated trace metal contents have been caught over a large area. Storys and Aberfoyle Creeks show severe impacts over a length of about ten kilometres.

INITIAL ANALYSIS OF TAILINGS SAMPLES

Virotec received a photograph of the site and six tailings samples from MRT to be used in a series of laboratory tests. Four of the six samples were from zinc-rich tailings (Zn-1/Zn-4) and two were from copper-rich tailings (Cu-1/Cu-2).

Sub-samples of each of the Zn- and Cu-rich tailing samples were air dried at 70°C for 24 hours and then tested for soil pH and EC[1]. Exchangeable salts (K^+, Na^+, Ca^{2+} and Mg^{2+}) were analysed to determine the amount of Virotec's Terra B™ soil conditioning reagent that would create the appropriate Ca:Mg ratio in the remediated soil profile[2].

Total actual acidity (TAA)[3] in the samples was analysed to determine acidity in the soil profile that would need to be neutralised to allow growth of poa grass (*Poa pratensis*). Total potential acidity

Figure 5: Samples were taken from this area in the disused tailings dam.

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Tailings samples from the Rossarden site were analysed in Virotec's own advanced laboratory.

(TPA) was determined using the chromium reducible sulphur (CRS) method[4] to indicate the amount of base ViroMine™ reagent that would need to be applied to ensure that no acid would be released in the future as a result of the oxidisation of any remaining sulphide minerals.

Trace metal availability was determined using the US EPA Toxicity Characteristic Leaching Procedure[5]. Total carbon (TC), total sulphur (TS) and total nitrogen (TN) were measured using a LECO CNS 2000 Analyser.

RESULTS OF INITIAL ANALYSIS

The results of the initial laboratory tests on the tailings are summarised overleaf in Table 1.

Sample Cu-1 was found during the analyses to be a clay sample that was not representative of tailings and was probably part of a bund that contained the tailings. All other samples were typical of tailings material.

All samples were characterised by high TAA values indicating that they had produced a substantial amount of acid that would require neutralisation. The CRS data indicated that sulphide mineral oxidisation was largely complete in the Cu-rich material and that future acid generation was likely to be minimal. However, some reactive sulphide minerals that could produce more acid in the future did remain in the Zn-rich tailings.

The Cu-2 samples had a reasonably high TC content indicating either high organic or inorganic carbon but without data the origin of the TC cannot be fully characterised.

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TABLE 1:

Table 1: Results of initial test work on Rossarden samples. EC is in µS cm^{-1}; CRS is given in %; TC, TS and TN are given in %; TAA is given in mmol acid per kg of soil; and exchangeable salts (K, Ca, MG and Na) are given in mg/kg.

Parameter	Cu-1	Cu-2	Zn-1	Zn-2	Zn-3	Zn-3
pH	2.49	2.64	3.24	3.08	3.52	3.32
EC	1860	789	1991	3100	2740	2729
CRS	0.007	0.007	0.072	0.072	0.072	0.072
TC	0.67	2.83	0.59	0.59	0.59	0.59
TS	0.63	0.23	0.45	0.45	0.45	0.45
TN	0.13	0.16	0.06	0.06	0.06	0.06
TAA	210.8	74.8	98.6	98.6	98.6	98.6
K	16.7	3.5	4.3	4.3	6.8	4.2
Na	11.5	12.2	9.9	12.4	12.6	7.3
Ca	25.0	8.0	500	1140	910	800
Mg	8.4	3.0	23.8	70.4	52.4	32.7

LABORATORY SCALE TESTS

The Zn-1/Zn-4 tailings samples were homogenised to form one representative sample for treatability testing but of the Cu-rich samples, only sample was used because Cu-1 was found to be a clay sample. 250g samples were mixed with three different Terra B™ blends in 500mL containers. The three Terra B™ blends used were specially created to provide the short-, medium- and long-term acid neutralising capacity and metals binding capacity that the laboratory tests had shown were required.

The Terra B™ blends were also optimised to provide an appropriate Ca:Mg ratio important for soil structure and plant growth, and sufficient nutrients and organic carbon to establish and sustain plant growth. Although time constraints meant that batch treatments had to be used to indicate treatment efficiency in laboratory test work, previous studies have shown that full-scale field treatments consistently provide better outcomes than laboratory batch tests as a result of continuing slow reactions involving the Terra B™ reagent; laboratory test are conservative and normally overestimate the amount of Terra B™ reagent required.

As per the original proposal by Virotec to MRT, all tailings samples were treated to achieve full treatment and partial treatment. Full treatment was designed to provide the maximum possible treatment of the contaminated tailings, including acid neutralisation and metals binding, whereas partial treatment was designed to allow neutralisation of TAA to a point where vegetation could probably be established.

Due to the low TPA, partial treatment should provide adequate neutralisation and allow a one-off treatment because the potential for ongoing oxidation of the tailings is limited by their low sulphide mineral content. Partial treatment was included as a treatment strategy to reduce application costs at this site and to determine the minimum application rates required. The treatment data are summarised below in Table 2.

TABLE 2:

Results of TCLP data on Cu-2 and Zn-1/4 tailings before and after treatment.

Parameter	Cu-2 Untreated	Cu-2 Maximum Treatment	Zn-1/4 Untreated	Zn-1/4 Maximum Treatment
pH	2.58	7.12	3.65	7.38
EC S/cm	956	813	1035	1458
Chromium (mg/L)	<0.1	<0.1	<0.1	<0.1
Copper (mg/L)	1.81	<0.1	18.38	<0.1
Manganese (mg/L)	<0.1	<0.1	1.69	<0.1
Iron (mg/L)	6.92	2.97	0.79	3.99
Cobalt (mg/L)	<0.1	<0.1	<0.1	<0.1
Nickel (mg/L)	<0.1	<0.1	<0.1	<0.1
Zinc (mg/L)	1.33	0.73	7.54	1.00

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A blend of Terra B™ reagent was used in treating the contaminated tailings.

IMPLEMENTATION OF VIROMINE™ TECHNOLOGY AT ROSSARDEN

ViroMine™ Technology involves several facets, including uniquely blended chemical products designed for specific mine remediation site conditions, application know-how related to the spreading and mixing methods and ratios, sampling procedures and project monitoring, process treatment designs and flows, and presentation of a range of treatment options, and specific plant and equipment requirements for each mine site. For the Rossarden mine project, this involved the development of a specially prepared blend of Terra B™ soil conditioning agent, and uniquely designed treatment methods.

a. Plant and Equipment

A minimum of equipment was needed to apply the treatment successfully. The Terra B™ was manufactured at a separate materials handling facility in Tasmania, where the required ingredients were assembled and mixed. Figure 6 shows the 26 tonnes of stockpiled Terra B™ at the materials handling facility prior to dispatching to Rossarden.

An excavator and loader were used to handle the Terra B™ over a two-day period, and a backhoe was used at the Rossarden site to distribute and mix the reagent into the uppermost layers of the tailings.

Figure 6: 26 tonnes of stockpiled Terra B™ reagent at the materials handling staging area in Tasmania.

b. Soil Sampling

Upon arrival at the Rossarden site it was found that the Zn-1/Zn-4 tailings samples that were supplied to the Virotec laboratory were different from most of the material to be treated at the site. Apparently, clay and rock material from the tailings dam bund wall had been pushed over the tailings in an effort to cap the tailings; the clay and rock cover formed a 30-50cm thick cover over the tailings. Furthermore, the site was not so much a tailings dam or compound but was an area that had tailings stockpiled on top of it.

Consequently, the material that was examined in the laboratory was not the same as that to be treated in the field. If only the upper three cm were treated as originally planned, then most of the treatment would have been applied to the clay and rock and not to the tailings. Hence, it was necessary to increase the treatment depth to 40-50 cm to ensure treatment of the uppermost tailings; this increased treatment depth should be sufficient to accommodate any effects resulting from the differences between the material tested in the laboratory and the material present at the site but some uncertainty will remain until on-site testing has been continued for several years.

c. Remediation of the Rossarden Tailings

Approximately 26 tonnes of Terra B™ with a moisture content of <5% was delivered to the site at Rossarden and mixed with the material to be treated using a backhoe.

Figure 7: Terra B™ being spread onto the zinc-enriched tailings with the backhoe.

Zn Tailings Area: Three 15m x 15m plots were marked out on the Zn tailings area. About eight tonnes of Terra B™ were applied to one plot (maximum treatment), about four tonnes were applied to another, and the third plot was left undisturbed as an untreated control. Where the Terra B™ was applied, it was first spread over the surface of the plot and then mixed in to the required depth using the backhoe.

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Figure 8 (Left): Terra B™ being mixed into the zinc-enriched tailings with the backhoe. Figure 9 (Right): The fully remediated Zn-enriched tailings plot at Rossarden prior to revegetation with poa grass seedlings.

Cu Tailings Area: Three 15m x 15m plots were marked out on the Cu tailings area and treated with Terra B™ in the same way as the plots in the Zn tailings area.

The Cu-2 tailings and Cu-1 tailings sites were incorporated into one site because this area was much smaller than anticipated. The initial treatment depth was to be 20-30cm – however, after assessment of the clay material and the low mass of tailings at this site the treatment depth was extended to 40-50cm.

RECOMMENDATIONS AND FUTURE WORK

Minerals Resources Tasmania has proposed that after evaluating the effectiveness of the ViroMine™ Technology to remediate the tailings and re-establish a grass cover on the tailings at Rossarden, a large-scale effort to fully remediate the site would be carried out.

a. Revegetation: One specific species of poa grass has been suggested by MRT as the species of choice for revegetation of these plots. However, it was suggested by Virotec that four to five grass species should be used instead of just one. Using multi-species allows for improved strike rates and would determine which species are most suitable for the ViroMine™ Technology and the site. A poly-culture versus a mono-culture reduces potential pest invasion by limiting food availability and also diversifies soil microbial populations.

MRT also proposed the poa grass be planted as seedlings in the remediated tailings – however, Virotec suggested that planting as seed rather than seedlings may be more efficient and cost effective. Virotec also suggested that eucalypt and acacia seed from the area should be incorporated with the grass seed to enhance overall habitat development. Nitrogen fixing grass species should be planted as should some herbaceous acacia species to assist in long-term nitrogen fixation.

b. Monitoring: Virotec suggested that grass growth is only one measure of the success of these trials, and that changes in soil chemistry are also an important measure of success. For this reason

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Virotec proposed that the control plots be left untouched so that direct comparisons of soil chemistry can be made between the full, partial and no treatment plots. Strike rates, health and vigour of emergent vegetation can be monitored as can metal analysis of leaf tissue.

Soil chemistry will be assessed every six to 12 months by extracting representative samples from each plot. It is envisaged that ten 250g samples will be collected from 0-10cm, ten 250g samples will be collected from 10-30cm, and ten 250g samples will be collected from 30-50cm. Each 250g sample will contain material <10mm in size. Each batch of samples from each depth will be homogenised into one sample and, using a cut and quarter technique, 200g samples will then be used to assess soil chemistry, including ph, EC, exchangeable metals, TN, TS, TC, K, Ca, Na, and Mg.

FOOTNOTES

[1] 5g samples were mixed with 25mL of Milli-Q, tumbled for one hour and centrifuged at 3000 RPM for five minutes; the supernatant was measured for pH and EC using a calibrated TPS pH/EC meter.

[2] 2g sample were mixed with 40mL of $C_2H_3O_2$, tumbled for one hour and centrifuged at 3000 RPM for five minutes; the supernatant was filtered to < 0.45µm and analysed by AAS.

[3] Lin, C., Lancaster, G., Sullivan, L. A., Mc Conchie, D. and Saenger, P. 2002. *Actual acidity in acid sulfate soils: chemical processes and analytical methods,* In "Acid sulphate soils in Australia and China", (Eds.) C. Lin, M. D. Melville and L. Sullivan. Science Press. Beijing.

[4] Sullivan, L. A., Bush, R. T., McConchie, D., Lancaster, G., Haskins, P. G. and Clark, M. W. 1999. "Comparison of peroxide-oxidisable sulfur and chromium reducible sulfur methods for determination of reduced inorganic sulfur in soil", *Australian Journal of Soil Research.* Vol. 37, pp. 255-265.

[5] USEPA, 2003. "Toxicity Characteristic Leaching Procedure: Method 1311", United States Environmental Protection Agency, July 1992.

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